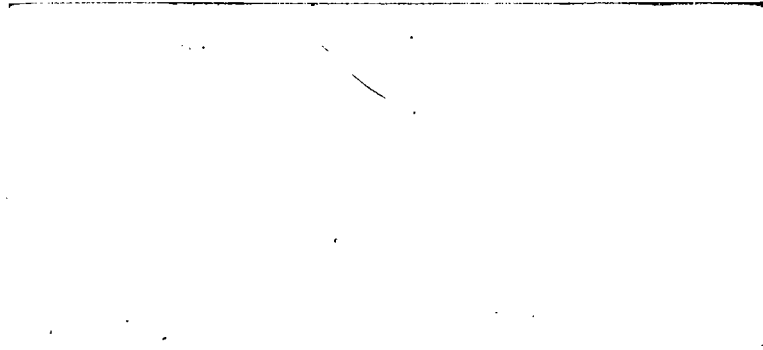Energy Systems Associates

E∫A

COMBUSTION OPTIMIZATION
STUDY AT THE COMMERCE REFUSE-TO-ENERGY
FACILITY

Volume I: Technical Report and Appendix A

Prepared for:

COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY
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For Submittal to:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
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SECTION 1.0

INTRODUCTION

Energy Systems Associates (ESA) was contracted by the County Sanitation Districts of Los Angeles County to perform a combustion optimization study at the Commerce Refuse-to-Energy Facility located in Commerce, California. The tests were required by Permit Condition No. 31 of the Permit to Construct for the Commerce facility (application No. 103650, granted June 5, 1985).

The objective of the test program was to evaluate combustion parameters to determine the optimum overfire air and excess air levels in terms of NOx emissions, CO emissions, and unit operation. A total of sixteen tests were performed from June 2 through June 13, 1988.

This report presents the results and conclusions of the combustion optimization study. Section 2.0 contains a description of the unit, with an emphasis on the combustion control system. A description of the test program is contained in Section 3.0. The results are presented in Section 4.0 and the program conclusions are presented in Section 5.0.

Appendix A, included in this volume, presents a more detailed description of the test procedures. A separate data volume contains test data, unit operating data, and quality assurance information.

SECTION 2.0

UNIT DESCRIPTION

The Commerce Refuse-to-Energy Facility consists of a municipal solid waste (MSW) fired boiler with a nominal charging rate of 320 to 380 tons per day of refuse and a steam flow rate of 115,000 lb/hr. The steam is used to generate 10 MW net (11.4 MW gross) of electricity for sale to Southern California Edison. A schematic of the system is shown in Figure 2-1.

The fuel portion of the combustion system at the facility consists of a charging chute into which MSW fuel is dropped, two rams which push the fuel into the furnace, and a grate consisting of three individually controlled reciprocating sections to move the fuel through the furnace as it burns. Combustion air is provided to the furnace from beneath the grate (undergrate air or UGA) and through six sets of nozzles located above the grate (overfire air or OFA). Approximately 5% of the total combustion air enters the furnace as cooling air through the standby natural gas burner. A forced draft fan supplies combustion air, and an induced draft fan at the base of the stack is used to maintain negative furnace pressure.

The combustion control system operates to adjust these parameters to maintain unit load and target furnace O_2 levels. A summary of how the combustion control system operates is presented below:

Ram speed - controlled primarily by the steam flow controller to provide enough fuel to maintain target steam flow. The controller signal is trimmed by the excess O_2 controller, and can also be manually trimmed by a bias controller.

Undergrate air flow - controlled by the steam flow controller so that the combustion process releases enough heat to maintain steam flows. There is a manually set upper limit so that fires are not extinguished during periods of rapid decrease in steam flow.

ESR 20528-557

BOILER

**QUENCH
REACTOR**
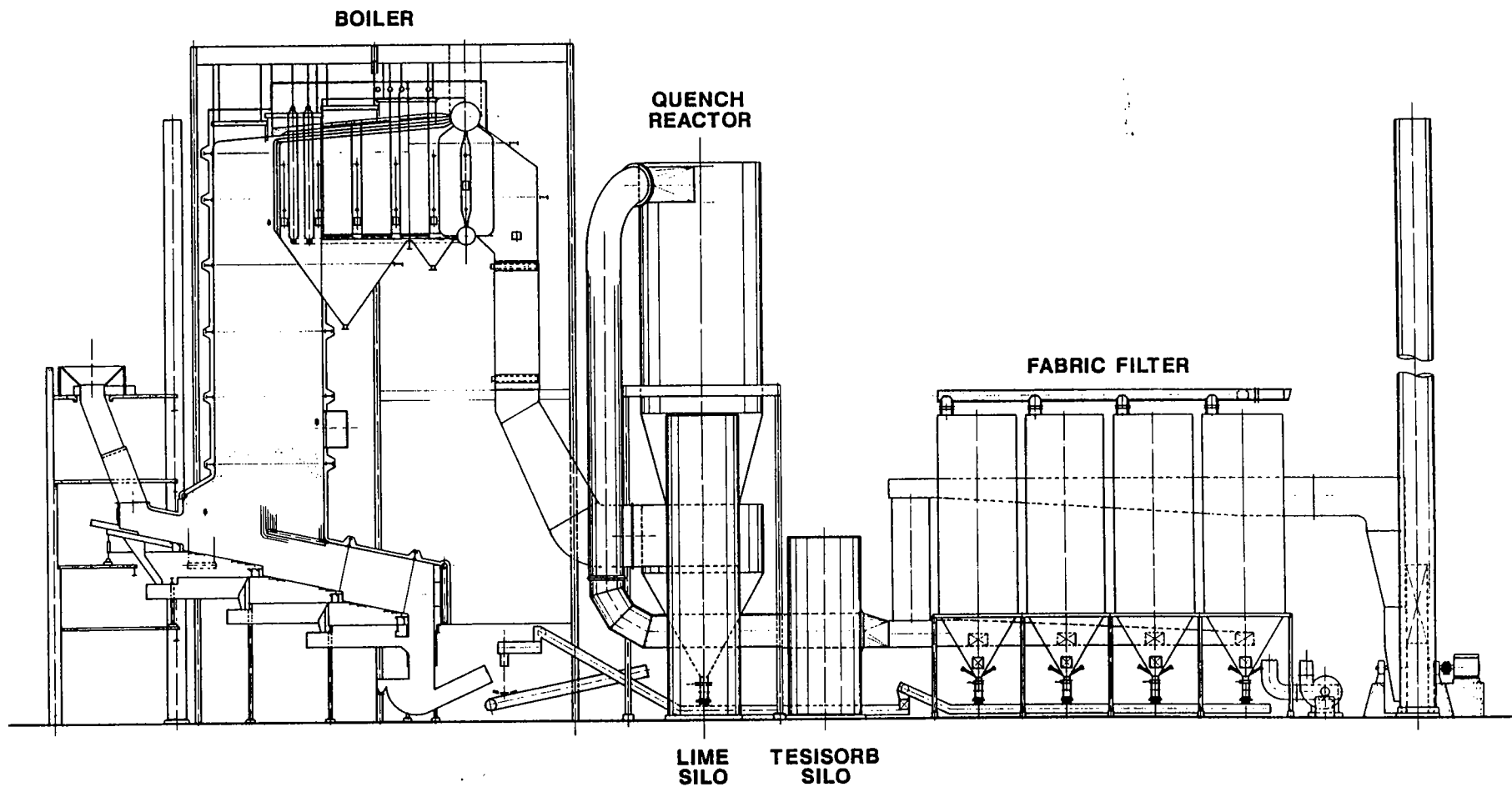
FABRIC FILTER

**LIME
SILO**

**TESISORB
SILO**

Figure 2-1. Commerce Refuse-to-Energy Facility boiler and APC equipment.

Overfire air flow - manually controlled to a constant flow rate, or automatically controlled and trimmed by the OFA/UGA ratio controller and the excess O_2 controller. Early tests showed no significant difference in operation or emissions for the two modes of operation, so subsequent tests were performed with the OFA controller in hand to more closely achieve the target OFA/UGA ratio.

Grate speed - the speeds of the three grate sections are individually controlled by the steam flow controller, and manually biased by the boiler operator. The bias settings are frequently adjusted to maintain the proper fuel bed thickness on the grates.

Air pollutant control is achieved by a number of techniques. NOx emissions are controlled by combustion control and NH3 injection into the furnace exit gas (Exxon Thermal DeNOx). Acid gas (SO_2 and HCl) control is achieved by a Teller/AAF spray dryer, which utilizes lime to collect the acid gases. Particulate control is by an American Air Filter baghouse.

The facility is base loaded, so its design operation is full capacity 24 hrs per day.

During the testing period, the boiler was charged with the normal refuse received at the Facility. This refuse is from the City of Commerce and is predominantly from commercial accounts. The boiler design criteria are presented in Table 2-1.

TABLE 2-1.
BOILER DESIGN PARAMETERS

Steam Flow	115,000 lb/hr
Steam Temperature	750 °F
Steam Pressure	650 psig
Refuse Feed Rate	320 to 380 TPD
Economizer Exit Temperature	460 °F
Feed Water Temperature	360 °F

SECTION 3.0

TEST PROGRAM

The test program was conducted in accordance with a test plan outlined in a letter dated January 23, 1987, from Michael Selna of the Commerce Refuse-to-Energy Authority to Emmanuel Ruivivar of the SCAQMD. The plan was approved, with certain conditions, by the SCAQMD in a letter dated April 1, 1987. The test plan and the SCAQMD response both specified conditions and sampling procedures to be used. These conditions were followed, and are described below.

3.1 TEST CONDITIONS

The test matrix is presented in Table 3-1. Sixteen separate tests were conducted at a total of nine test conditions. The nine conditions encompassed a test matrix of three excess air levels (furnace set points of 5.5, 7.0, and 8.5 % O_2) by three OFA/UGA ratios (30/70%, 40/60%, and 50/50%). This matrix covers the normal range of operating conditions for these two variables.

TABLE 3-1.
TEST MATRIX FOR COMBUSTION OPTIMIZATION PROGRAM
Numbers in table indicate test numbers

Target OFA, %	Furnace O_2 set point (% wet)		
	5.5%	7.0%	8.5%
30	3,15	1,2,4	8
40	5	6,9	7,16**
50	12*	11	10,13,14**

* Actual set point 6.0% O_2; unable to control at 5.5%
** Actual set point 8.0% O_2

For each test, unit operation was established at the desired test conditions and allowed to stabilize. NH_3 flow to the Thermal deNOx system was shut off, so that the impact of combustion changes on NOx production could be evaluated directly. The combustion control system was operated as described in Section 2.0, and all other unit operating conditions were normal. Frequent checks of the composition of the refuse being fed to the boiler were made by visual observation and by conversations with the crane operators. There was some variation in the composition of the fuel mix being fed to the boiler, but the variation was well within the normal bounds of operation.

3.2   TEST PROCEDURES

Test procedures involved analyzing the stack gases continuously for NOx, CO, O_2, and CO_2; recording the test data with a data logger; and collecting unit data and monitoring unit operation.

Gaseous emissions at the stack were measured using ESA's continuous emissions monitor (CEM) described in Appendix A. A heated Teflon line and supercooled ice bath were used to prevent loss of NO_2 in the sampling system. Single point gaseous sampling was performed since earlier tests had shown no significant stratification of gaseous species.

The type of instruments, range, and outputs used are listed in Table 3-2. CO was measured using two analyzers: a Teco analyzer with very low range capability and no CO_2 interference, and a Horiba analyzer with a lower range of 0-1000 ppm and slight CO_2 interference (approximately 1 ppm CO per % CO_2, or 8-10 ppm CO for these tests). The Teco analyzer was used as the primary instrument. During the tests there were instances where CO values momentarily exceeded the 0-200 ppm range set for the Teco. In these cases data from the Horiba analyzer was used. Comparison of the results from the two analyzers showed excellent agreement (within 3 ppm CO after correction for CO_2 interference).

TABLE 3-2
GASEOUS INSTRUMENTS USED FOR
COMMERCE COMBUSTION OPTIMIZATION PROGRAM

Species	Instrument Mfr.	Scale	Output to:	
			Strip Chart	Data Logger
NOx	Teco	0-250 ppm	X	X
CO	Teco	0-200 ppm	X	X
O_2	Teledyne	0-25%	X	X
CO	Horiba	0-1000 ppm		X
CO_2	Horiba	0-25%		X

Instrument calibrations were performed at the start of each test, and system bias tests were performed once or twice per day. All calibration drift and system bias data were within EPA and SCAQMD specifications.

The sampling system bias was also checked using a gas containing approximately 25 ppm NO_2 and the loss in NOx was less than 1% of scale, thus verifying that any NO_2 that might be present in the sample gas would be conserved. However, no detectable NO_2 was measured during any of the eleven times that NO vs. NOx measurements were checked.

Data from the instruments was recorded using a Metrosonics d721 data logger. Instrument readings were taken at a frequency of once per second and combined into 5-minute averages. At the end of each test or day, the data was stored on a diskette for later computer retrieval.

During each test, data for a wide variety of unit operating parameters was collected using plant instrumentation. Key parameters such as unit load, UGA and OFA flow, and furnace O_2 were recorded on a 15-minute average basis. Other parameters such as combustion control settings and emission trends were recorded at least once per test. Unit operating data is included in Appendix D (in Volume II).

SECTION 4.0

RESULTS

The results of the tests are summarized in Table 4-1. Included in the table are unit operating conditions and emission results. The following discussions cover unit operation, NOx emissions, CO emissions, and the relationship between CO and NOx emissions.

4.1   UNIT OPERATION

Unit operation was steady for most of the test conditions, but there were certain tests during which it was difficult to maintain set point conditions, 100% load, or both. These tests are discussed below.

Test 2 - 7.0% set point, 30% OFA. During this test there were frequent "burnout" conditions, in which the fuel on the grate burns rapidly and the fuel bed becomes too thin to support a strong flame. Burnout conditions are normally associated with reductions in boiler load and sometimes with short-term increases in CO concentrations. Because of the unstable operation, average furnace O_2 was 7.6% compared to the set point of 7.0%.

Test 3 - 5.5% O_2, 30% OFA: this test was performed at minimum excess oxygen and minimum OFA. Combustion control was difficult due to operation at the edge of the normal operating range for both parameters. The test condition was repeated in Test 15, and better combustion control was achieved for that test.

Tests 6 and 9 - 7.0% O_2, 40% OFA: during these two tests there operation was stable and CO emissions were very low. The actual O_2 levels for the tests were 6.2 and 6.4%, however, because the O_2 controller was unable to maintain the target level.

Table 4-1. Commerce combustion optimization test summary.

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date, 1988	6/2	6/3	6/3	6/7	6/7	6/7	6/8	6/8	6/8	6/9	6/9	6/9	6/10	6/10	6/10	6/13
Start time	1045	0900	1330	0800	1515	1752	0833	1047	1314	0709	0936	1320	0801	1025	1219	0910
Stop time	1310	1320	1630	1105	1715	1952	1033	1247	1514	0909	1136	1520	0951	1111	1419	1127
Load, MW gross	11.5	10.7	11.4	10.9	11.6	11.5	11.9	11.1	11.6	11.6	10.9	11.3	10.2	11.2	11.4	10.5
O2 set point	7.0	7.0	5.5	7.0	5.5	7.0	8.5	8.5	7.0	8.5	7.5	6.0	8.5	8.0	5.5	8.0
Actual furn O2	6.9	7.6	5.8	7.4	5.6	6.2	7.2	8.2	6.4	7.7	7.4	6.7	8.1	7.3	5.7	8.0
Target OFA, %	30	30	30	30	40	40	40	30	40	50	50	50	50	50	30	40
Actual OFA, %	34	29	30	29	44	40	40	28	40	47	48	48	43	43	30	40
UGA flow, klb/hr	126	130	118	122	93	107	112	106	106	98	91	91	112	114	113	123
OFA flow, klb/hr	66	53	51	50	72	73	73	50	71	86	85	85	86	87	48	80
Total air, klb/hr	192	183	169	172	165	180	185	156	177	184	176	176	198	201	161	203
Stack emissions:																
NOx, ppm	95	125	79	110	146	131	90	102	126	118	123	124	105	117	104	95
NOx, ppmc	169	229	127	178	212	241	141	170	191	201	213	199	188	198	153	167
CO, ppm	22	64	395	48	18	10	63	74	17	8	8	10	21	22	117	27
CO, ppmc	39	117	637	78	26	18	100	124	25	14	13	15	38	37	173	48
O2, %	10.8	11.1	9.8	9.8	8.6	11.4	11.9	10.2	9.1	10.4	10.5	9.7	10.9	10.4	8.8	10.7

Tests 7, 8, 10, and 13 - 8.5% O_2, various OFA levels: the O_2 controller could maintain O_2 levels of only 7.2 to 8.2% for these tests. CO emissions were higher for these tests than for some of the other tests, due possibly in part to the difficulties in controlling the high O_2 levels and partly to the quenching effect of high air velocities through the furnace.

Impacts of unit operation on emissions are discussed further in Sections 4.2 and 4.3.

4.2   NOx EMISSIONS

The results of the NOx tests are shown in Figures 4-1 and 4-2. Figure 4-1 shows NOx emissions plotted vs. furnace O_2 for the three OFA levels tested, and Figure 4-2 shows NOx plotted against OFA for the three excess O_2 levels.

The figures show that uncontrolled NOx emissions from the furnace did not correlate with either excess oxygen or overfire air rate. NOx levels for the sixteen tests ranged from 127 to 241 ppmc (ppmc indicates parts per million by volume, corrected to 3% O_2), and averaged 186 ppmc.

Both figures show NOx as essentially a scatter plot, with no strong correlations. There are some possible correlations evident, but for the most part they are weak and inconsistent. For example, there is a slight positive correlation of NOx vs. O_2 at 30% OFA (r = 0.67), but a slight negative correlation of NOx vs. O_2 at 40% OFA (r = -0.72). The only strong correlation is NOx vs. OFA at low O_2 levels (r = 0.92)

These results are at first surprising, since it might have been expected that NOx would increase with higher O_2 levels and decrease with increasing overfire air levels. These statements are based on NOx trends with other fuels such as oil, coal, and wood.

For stoker-fired boilers fuel nitrogen is the major source of NOx, as opposed to thermal NOx formed from reaction of atmospheric nitrogen at high flame temperatures. In general, techniques which reduce available oxygen in the primary combustion zone (for this boiler the primary combustion zone would be the area immediately above the grate) reduce the formation of NOx from

NOx vs O2 at Three OFA Levels
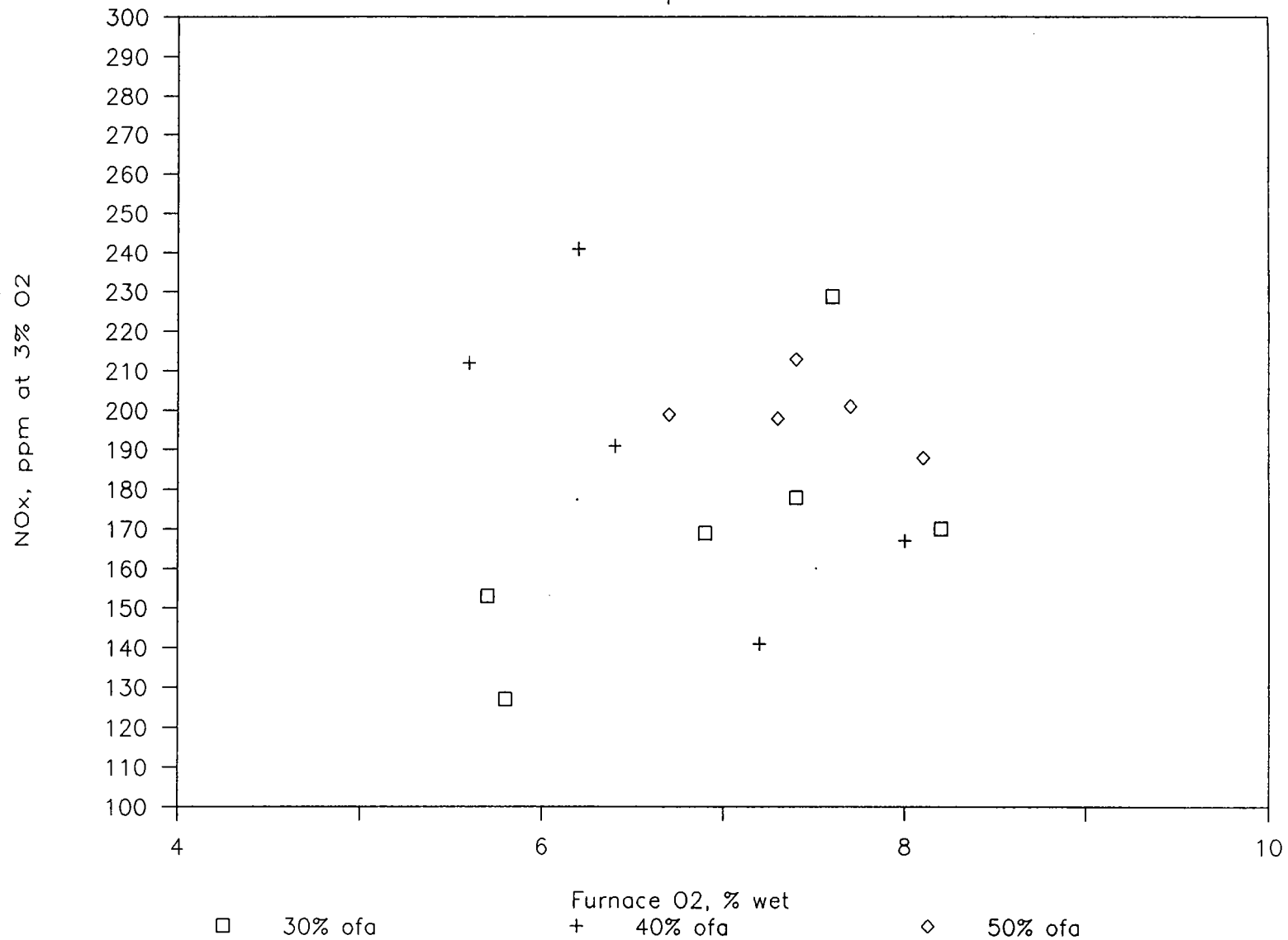
Combustion optimization tests

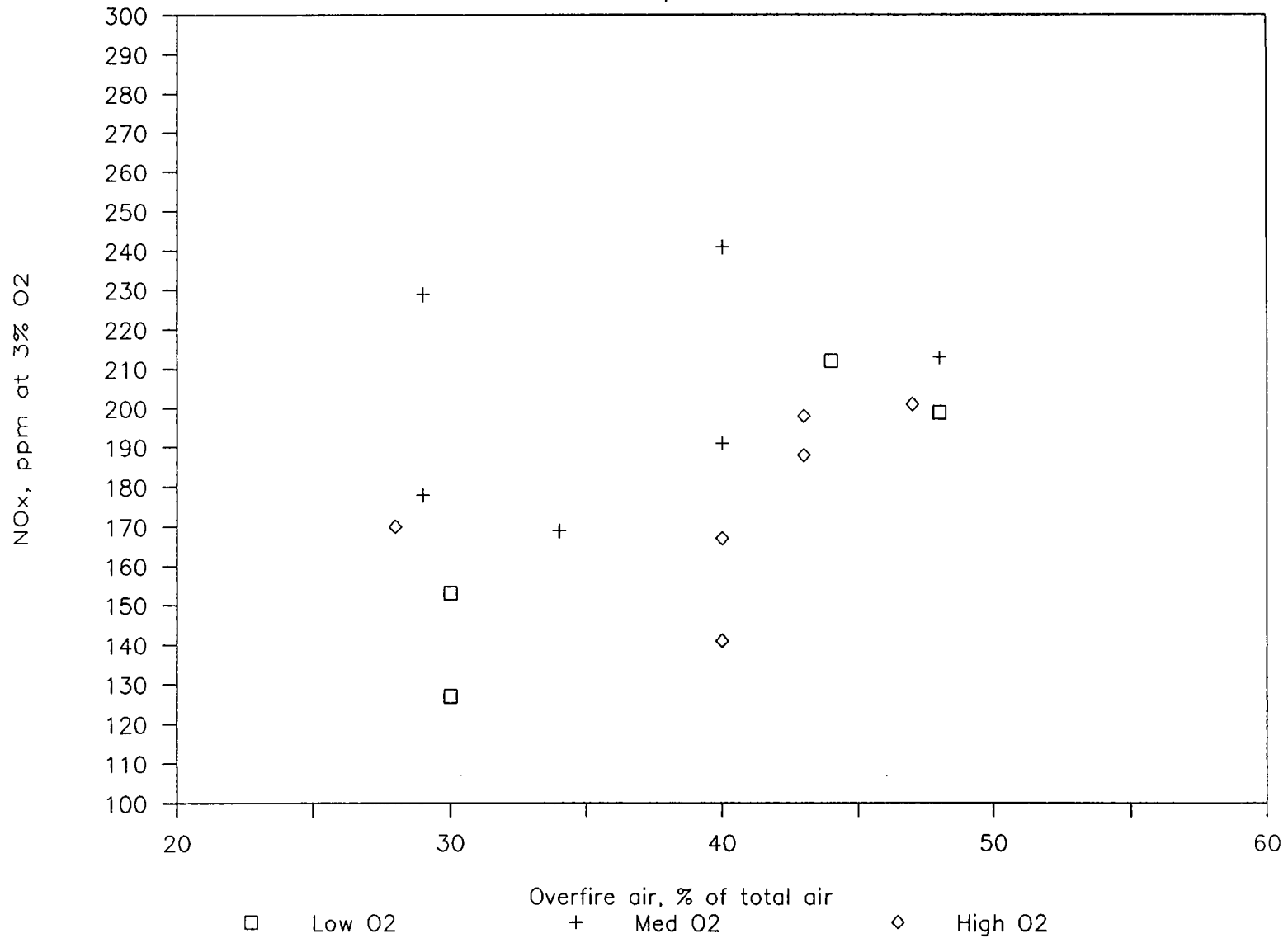Figure 4-1.   NOx vs O_2, Commerce combustion optimization tests.

Figure 4-2. NOx vs. overfire air, Commerce combustion optimization tests.

fuel-bound nitrogen. Reduced overall excess air levels and increased overfire air will reduce available oxygen in the fuel bed and would be expected to reduce NOx formation.

However, on a refuse fired boiler there are a number of fuel related variables that impact NOx formation. These include fuel nitrogen content, fuel heating value, the size and shape of fuel components, how the fuel is mixed, and the depth and evenness of the fuel bed on the grate. All of these factors can impact NOx formation, and they all vary significantly within the normal range of boiler operation.

The results shown in Figures 4-1 and 4-2 indicate that variability in NOx due to fuel-related factors is so great that any impact of air-related factors cannot be seen. Thus, there is no OFA/O_2 combination which can be demonstrated to be best in terms of NOx emissions.

4.3 CO EMISSIONS

The results of the CO tests are shown in Figures 4-3 through 4-6. Figures 4-3 and 4-4 show CO plotted vs. O_2 (using two different scales for plotting CO values), and Figures 4-5 and 4-6 show CO plotted vs. OFA. Note that the graphs identify Test 7 as an outlier from the standpoint of CO emissions. As discussed in Section 4.1, there were some control problems during the test, so its result is excluded from the following discussions.

As noted in Section 4.1, combustion control was difficult during Test 3 due to simultaneous operation at low O_2 and low OFA. CO emissions for Test 3 were 637 ppmc. The test conditions were repeated in Test 15 and better combustion control was achieved. Average CO for Test 15 was 173 ppmc. These results indicate the variability of CO emissions at a test condition which represents a limiting edge to normal operation.

The figures show some clear trends:

1. CO is below 50 ppmc for all O_2 levels at 40 and 50% OFA.

2. At 40 and 50% OFA, CO increases slightly with excess air.
   At 30% OFA, there is a U-shaped curve of CO vs. O_2, with CO increasing sharply at both low and high O_2 levels.

CO vs O2 at Three OFA Levels

Combustion optimization tests

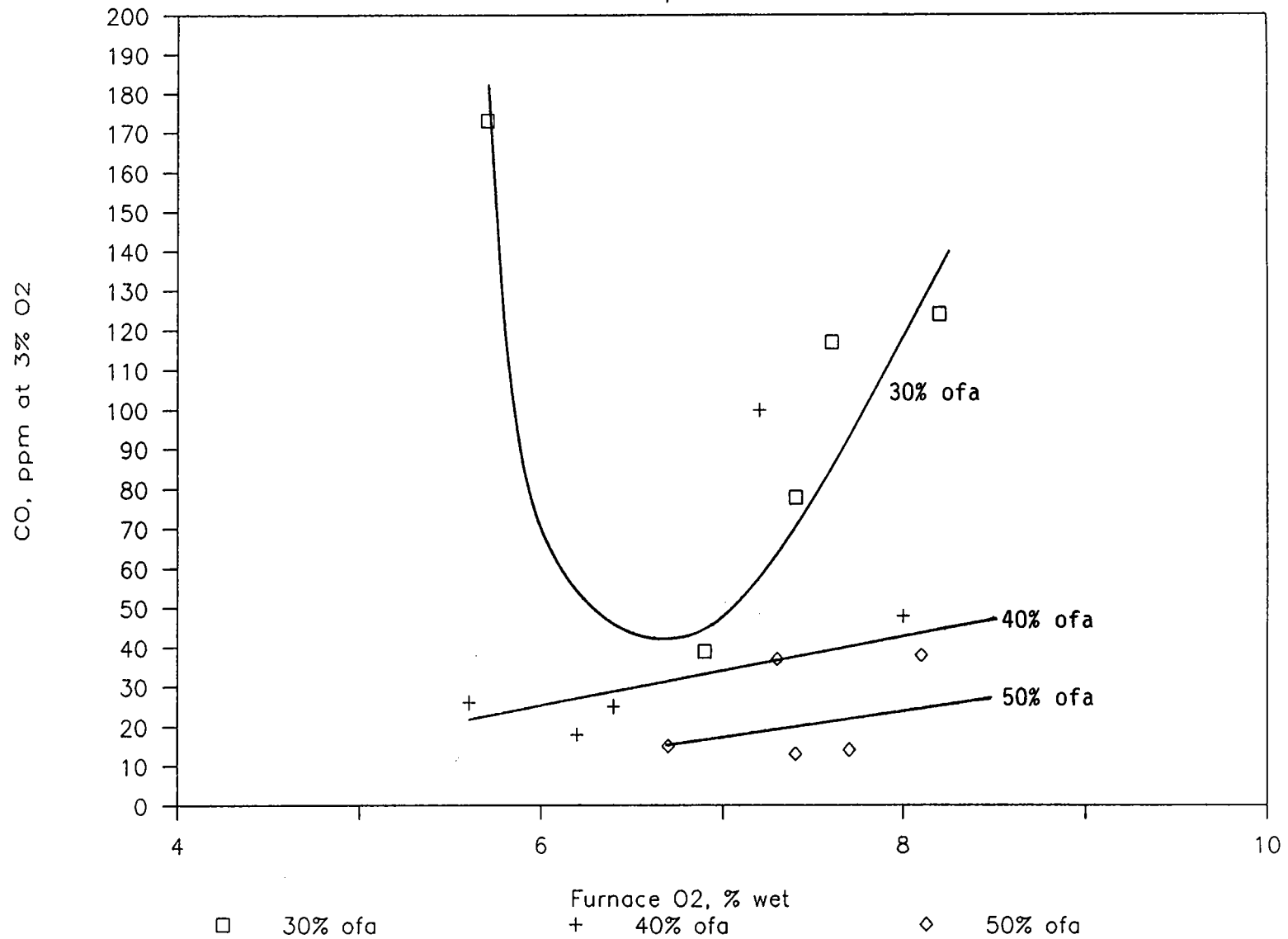Figure 4-3. CO vs. furnace O_2, expanded scale graph.

CO vs O2 at Three OFA Levels
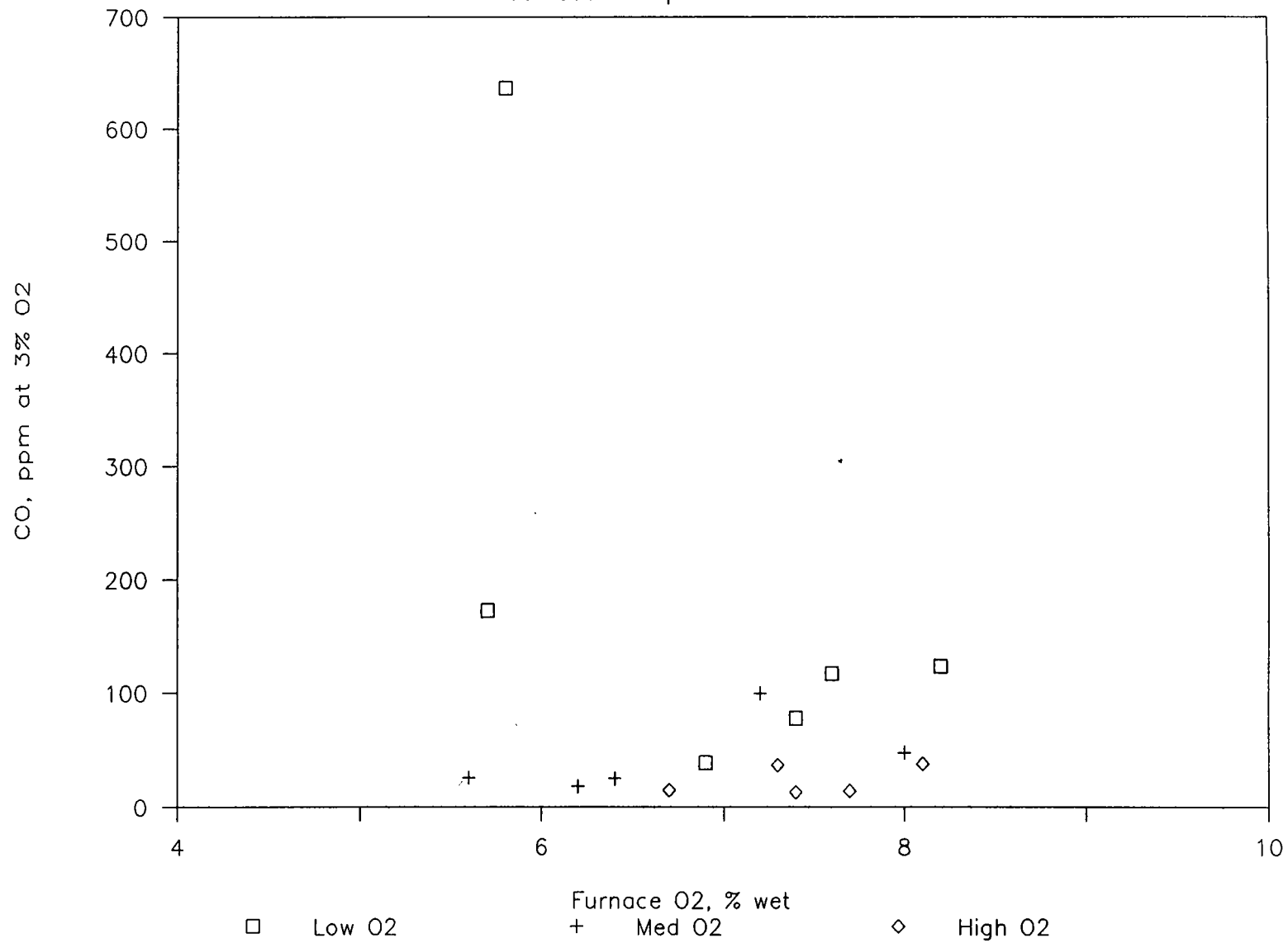
Combustion optimization tests

Figure 4-4. CO vs. furnace O_2, full scale graph.

CO vs OFA at Three O2 Levels
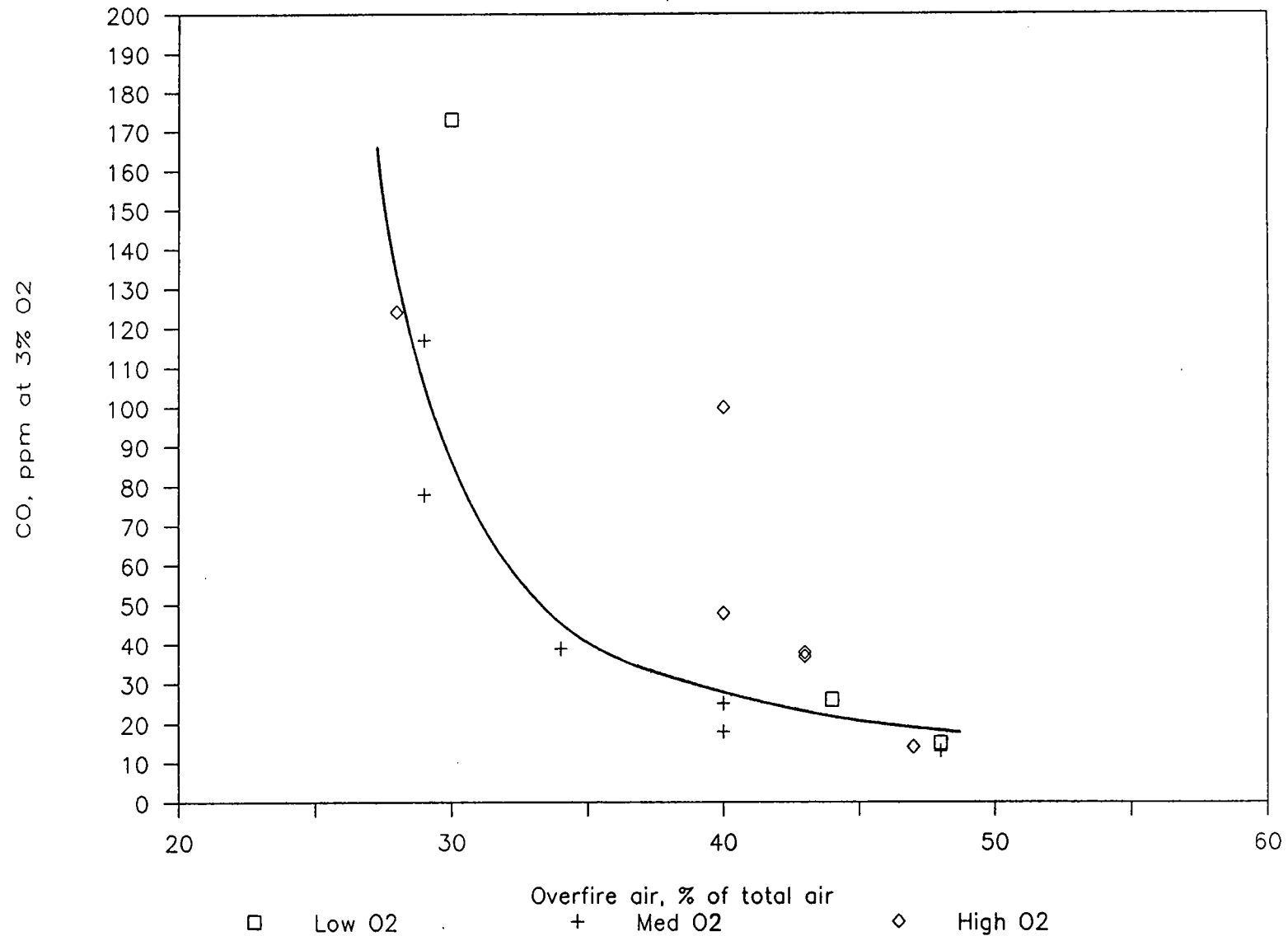
Combustion optimization tests

Figure 4-5.   CO vs. overfire air, expanded scale graph.

CO vs OFA at Three O2 Levels
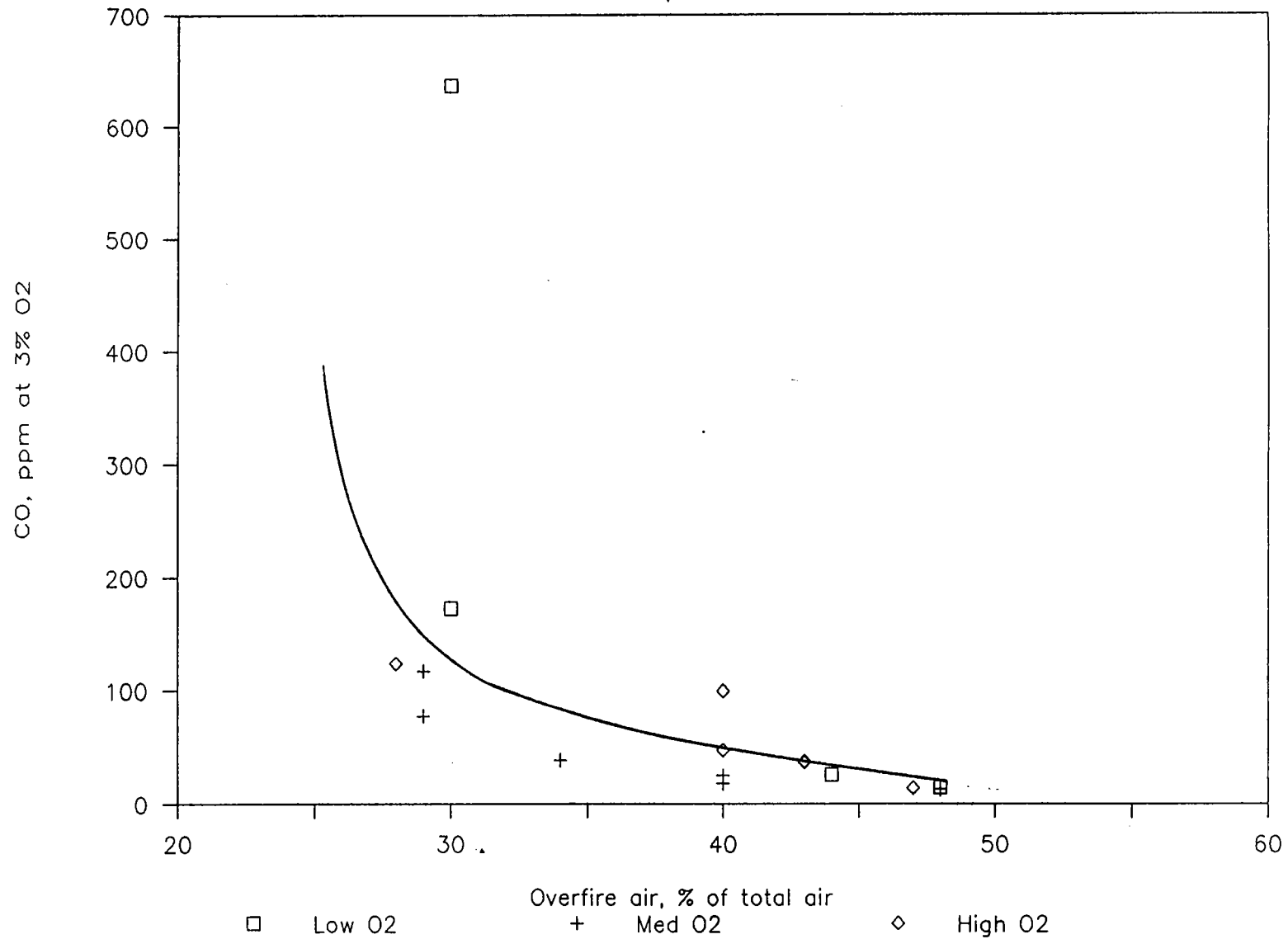
Combustion optimization tests

Figure 4-6.   CO vs. overfire air, full scale graph.

3. CO is below 50 ppmc for all tests at OFA levels above
    30%. At 30% OFA, CO levels range from 50 to 180 ppmc.

These results indicate that there is a threshold level above which
there is good mixing and completion of combustion at the overfire air
injection location. This was confirmed by visual observation which indicated
that flames were lower in the furnace at high OFA levels.

The conclusion to be drawn from these results is that CO can be
maintained at low, steady levels over a wide range of operating conditions.
With the exception of very low OFA levels, the variation of CO with O_2 or OFA
is slight.

4.4   CO/NOx RELATIONSHIP

Although the data presented in Section 4.2 indicated that NOx
emissions did not correlate with O_2 or OFA level, a detailed review of the
data did show one factor that NOx did correlate with: CO concentration.

Figure 4-7 shows a plot of NOx emissions vs. CO emissions. Although
there is significant data scatter, the figure shows that lower NOx emissions
tend to correlate with higher CO emissions. This is not surprising in that
the factors which favor low CO emissions (high temperatures, good air/fuel
mixing) also tend to favor high NOx emissions, and the conditions which favor
high CO emissions tend to favor low NOx emission.

NOx vs CO

Combustion optimization tests
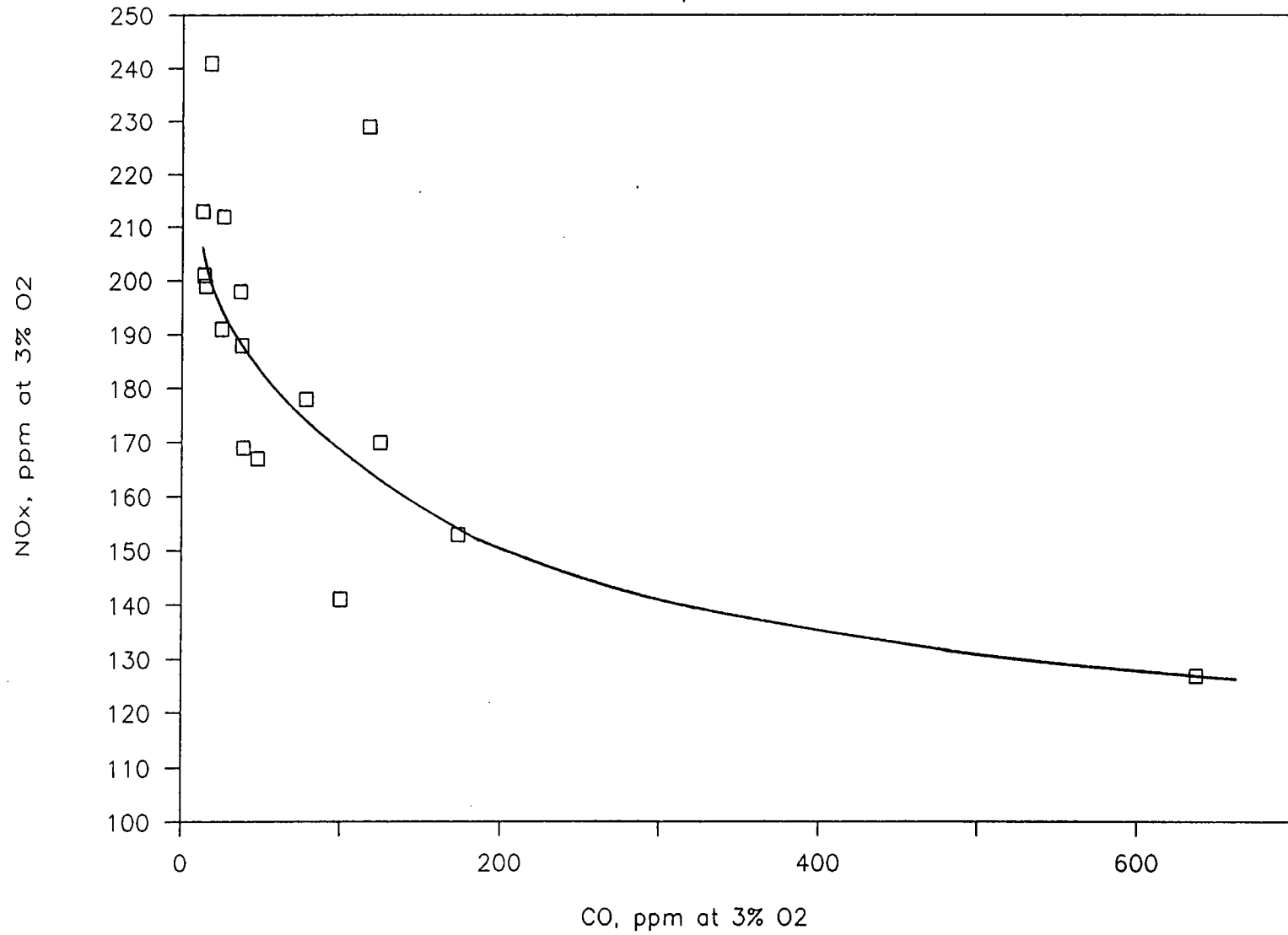
Figure 4-7. NOx vs. CO.

SECTION 5.0

CONCLUSIONS

Based on the results of the combustion optimization test program, the following conclusions are drawn:

1. NOx emission levels were so variable due to normal fluctuations in fuel composition and furnace operation that no impact of excess oxygen or overfire air on NOx could be discerned.

2. CO levels were below 50 ppmc at all conditions above 30% overfire air.

3. The only discernible trend for NOx emissions was a negative correlation with CO emissions.

4. Stable operation with low CO and NOx emissions can be maintained over a wide range of operating conditions.

ESR 20528-558

APPENDIX A

MEASUREMENT PROCEDURES

Continuous Emissions Monitoring System
Oxygen (O_2) by Continuous Analyzer
Carbon Dioxide (CO_2) by Continuous Analyzer
NO/NOx by Continuous Analyzer
Carbon Monoxide (CO) by Continuous Analyzer

ESR 20528-557

Continuous Emissions Monitoring System

O_2, CO, CO_2, NO, NOx, and SO_2 are measured using an extractive continuous emissions monitoring (CEM) package, shown in the following figure. This package is comprised of three basic subsystems. They are: (1) the sample acquisition and conditioning system, (2) the calibration gas system, and (3) the analyzers themselves. This section p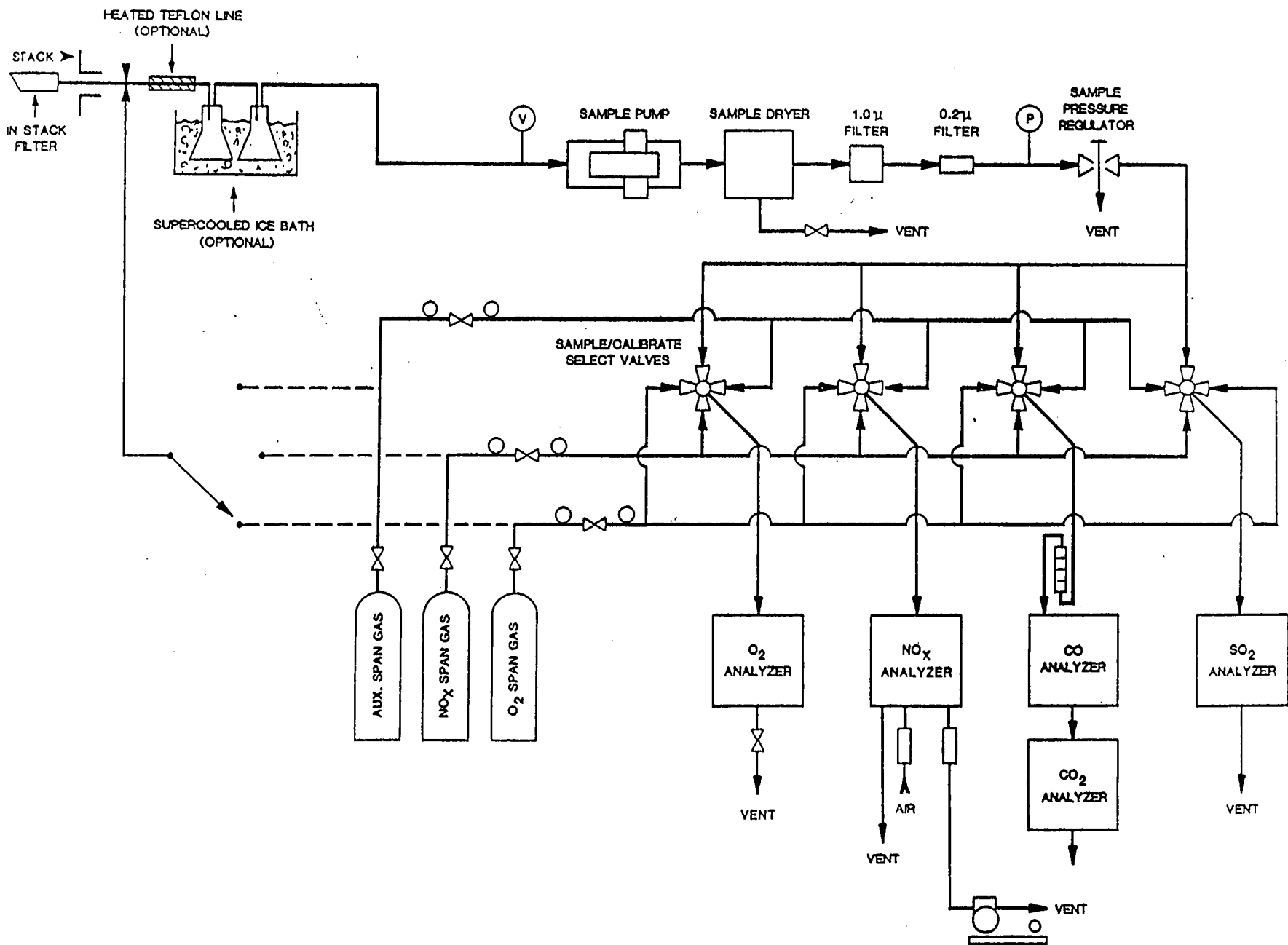resents a description of the sampling and calibration systems. Descriptions of the analyzers used in this program and the corresponding reference test methods follow. Information regarding quality assurance information on the system, including calibration routines and system performance data follows.

The sample acquisition and conditioning system contains components to extract a representative sample from the stack or flue, transport the sample to the analyzers, and remove moisture and particulate material from the sample. In addition to performing the tasks above, the system must preserve the measured species and deliver the sample for analysis intact. The sample acquisition system extracts the sample through a stainless steel probe. The probe is insulated or heated as necessary to avoid condensation. If the particulate loading in the stack is high, a sintered stainless steel filter is used on the end of the probe.

Where water soluble NO_2 and/or SO_2 are to be measured, the sample is drawn from the probe through a heated Teflon sample line into a supercooled (approximately -20 °C) water removal trap. The trap consists of stainless steel flasks in a bath of dry ice and antifreeze. If dry ice is not locally available, ice and rock salt are used. This design removes the water vapor by condensation and freezes the liquid quickly. The contact between the sample and liquid water is minimized. Since the solubility of the NO_2 and SO_2 in ice is negligible, these species are conserved. This system meets the requirements of EPA Method 20. The sample is then drawn through a Teflon transport line and particulate filter, into the sample pump. The pump is a dual head, diaphragm pump. All sample-wetted components of the pump are stainless steel or Teflon. The pressurized sample leaving the pump flows through a stainless steel refrigerated (38 °F) compressed air dryer for final moisture removal. A drain line and valve are provided to constantly expel any condensed moisture from the dryer. After the dryer, the sample is directed into a distribution manifold. Excess sample is vented through a back-pressure regulator, maintaining a constant pressure of 5-6 psig to the analyzers.

The calibration system is comprised of two parts: the analyzer calibration, and the system calibration check (dynamic calibration). The analyzer calibration equipment includes pressurized cylinders of certified span gas. The gases used are, as a minimum, certified to ±1% by the manufacturer where necessary, to comply with reference method requirements. EPA Protocol 1 gases are used. The cylinders are equipped with pressure regulators which supply the calibration gas to the analyzers at the same pressure and flow rate as the sample. The selection of zero, span, or sample gas directed to each analyzer is accomplished by operation of the sample/calibration selector valves.

ESR 20528-557

STACK

HEATED TEFLON LINE
(OPTIONAL)

IN STACK
FILTER

SUPERCOOLED ICE BATH
(OPTIONAL)

V

SAMPLE PUMP

SAMPLE DRYER

1.0 μ
FILTER

0.2 μ
FILTER

P

SAMPLE
PRESSURE
REGULATOR

VENT

VENT

SAMPLE/CALIBRATE
SELECT VALVES

AUX. SPAN GAS

NO_x SPAN GAS

O_2 SPAN GAS

O_2
ANALYZER

NO_x
ANALYZER

CO
ANALYZER

SO_2
ANALYZER

VENT

AIR

VENT

CO_2
ANALYZER

VENT

VENT

VENT

Continuous Emissions Monitoring System

The system calibration check is accomplished by transporting the same gases used to zero and span the analyzers to the sample conditioner inlet (probe exit). The span gas is exposed to the same elements as the sample and the system response is documented. Where the supercooled moisture removal system is used, water is added to the knockout flasks before the pre-test check. The analyzer indications for the system calibration check must agree within 3% of the analyzer calibration. Values are adjusted and changes/ repairs are made to the system to compensate for any difference in analyzer readings. Specific information on the analytical equipment and test methods used is provided in the following pages.

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Method:	Oxygen (O_2) by Continuous Analyzer
Applicable Ref. Methods:	EPA 3A, EPA 20, ARB 1-100, BA ST-14
Principle:	A sample is continuously drawn from the flue gas stream, conditioned, and conveyed to the instrument for direct readout of O_2 concentration.
Analyzer:	Teledyne Model 326A
Measurement Principle:	Electrochemical cell
Ranges:	0-5, 0-10, 0-25% O_2
Accuracy:	±1% of full scale
Output:	0-100 mV, linear
Interferences:	Halogens and halogenated compounds will cause a positive interference. Acid gases will consume the fuel cell and cause a slow calibration drift.
Response Time:	90% <7 seconds
Sampling Procedure:	A representative flue gas sample is collected and conditioned using the CEM system described previously. If Method 20 is used, that method's specific procedures for selecting sample points are used. Otherwise, the procedures described in the report are used to select sample locations.
Analytical Procedure:	An electrochemical cell is used to measure O_2 concentration. Oxygen in the flue gas diffuses through a Teflon membrane and is reduced on the surface of the cathode. A corresponding oxidation occurs at the anode internally, and an electric current is produced that is proportional to the concentration of oxygen. This current is measured and conditioned by the instrument's electronic circuitry to give an output in percent O_2 by volume.
Special Calibration Procedure:	The measurement cells used with the O_2 instrument have to be replaced on a regular basis. After extended use, the cells tend to produce a nonlinear response. Therefore, a three-point calibration is performed at the start of each test day to check for linearity. If the response is not linear (± 2% of scale), the cell is replaced.

Method: Carbon Dioxide (CO_2) by Continuous Analyzer

Applicable
Ref. Methods: EPA 3A, ARB 1-100, BA ST-5

Principle: A sample is continuously drawn from the flue gas stream,
                    conditioned, and conveyed to the instrument for direct
                    readout of CO_2 concentration.

Analyzer: Horiba PIR 2000

Measurement
Principle: Nondispersive infrared (NDIR)

Accuracy: ±1% of full scale

Ranges: 0-5, 0-10, 0-25%

Output: 0-10 mV

Interferences: A possible interference includes water.

Response
Time: 1.2 seconds

Sampling
Procedure: A representative flue gas sample is collected and con-
                    ditioned using the CEM system described previously.
                    Sample point selection is as described in the report.

Analytical
Procedure: Carbon dioxide concentrations are measured by short
                    pathlength nondispersive infrared analyzers. These
                    instruments measure the differential in infrared energy
                    absorbed from energy beams passed through a reference
                    cell (containing a gas selected to have minimal absorp-
                    tion of infrared energy in the wavelength absorbed by
                    the gas component of interest) and a sample cell through
                    which the sample gas flows continuously. The differen-
                    tial absorption appears as a reading on a scale of 0 to
                    100%.

Method:	NO/NOx by Continuous Analyzer

Applicable
Ref. Methods: EPA 7E, EPA 20; ARB 1-100, BA ST-13A

Principle: A sample is continuously drawn from the flue gas stream, conditioned, and conveyed to the instrument for direct readout of NO or NOx.

Analyzer: Teco Model No. 10AR

Measurement
Principle: Chemiluminescence

Accuracy: ±1% of full scale

Ranges: 0-2.5, 0-10, 0-25, 0-100, 0-250, 0-1000, 0-2500, 0-10,000 ppm

Output: 0-10 mV

Inferences: Compounds containing nitrogen (other than ammonia) may cause interference.

Response
Time: 90%, 1.5 seconds (NO mode) and 1.7 seconds (NOx mode)

Sampling
Procedure: A representative flue gas sample is collected and conditioned using the CEM system described previously. If EPA Method 20 is used, that method's specific procedures for selecting sample points are used. Otherwise, the procedures described in the report are used to select sample locations.

Analytical
Procedure: The oxides of nitrogen monitoring instrument is a chemiluminescent nitric oxide analyzer. The operational basis of the instrument is the chemiluminescent reaction of NO and ozone (O_3) to form NO_2 in an excited state. Light emission results when excited NO_2 molecules revert to their ground state. The resulting chemiluminescence is monitored through an optical filter by a high sensitivity photomultiplier tube, the output of which is electronically processed so it is linearly proportional to the NO concentration. The output of the instrument is in ppmV.

When NO_2 is expected to be present in the flue gas, a supercooled water drop-out flask will be placed in the sample line to avoid loss of NO_2. Since NO_2 is highly soluble in water, "freezing out" the water will allow the NO_2 to reach the analyzers for analysis. The analyzer measures NO only. In the NOx mode, the gas is passed through a moly converter which converts NO_2 to NO and a total NOx measurement is obtained. NO_2 is determined as the difference between NO and NOx. Use of a moly converter instead of a stainless steel converter eliminates NH_3 interference; NH_3 is converted to NO with a stainless converter, but not with a moly converter.

Method: Carbon Monoxide (CO) by Continuous Analyzer

Applicable
Ref. Methods: EPA 10; ARB 1-100; BA ST-6

Principle: A sample is continuously drawn from the flue gas stream,
                 conditioned, and conveyed to the instrument for direct
                 readout of CO concentration.

Analyzer: Horiba, Model PIR 2000

Measurement
Principle: Nondispersive infrared (NDIR)

Accuracy: ±1% of full scale

Ranges: 0-500, 0-1500, 0-2500 ppm

Output: 0-10 mV

Interferences: Any substance (e.g., cyanogen, methyl azide, CO_2, H_2O)
                 having a strong absorption of infrared energy will
                 interfere to some extent.

                 Interference by H_2O is less than 0.5 ppm based on manu-
                 facturer's interference data and moisture tests conduc-
                 ted at the sample conditioner outlet. CO_2 interference
                 is up to 10 ppm, and is corrected based on measured CO_2
                 values and interference factors measured by ESA.

Response
Time: 1.2 seconds

Sampling   A representative flue gas sample is collected and con-
Procedure: ditioned using the CEM system described previously.
                 Sample point selection has been described previously.

Analytical   Carbon monoxide concentrations are measured by short
Procedure: pathlength nondispersive infrared analyzers. These
                 instruments measure the differential in infrared energy
                 absorbed from energy beams passed through a reference
                 cell (containing a gas selected to have minimal absorp-
                 tion of infrared energy in the wavelength absorbed by
                 the gas component of interest) and a sample cell through
                 which the sample gas flows continuously. The differen-
                 tial absorption appears as a reading on a scale of 0 to
                 100% and is then related to the concentration of the
                 specie of interest by calibration curves supplied with
                 the instrument.

Comparison to   Use of this method with the CO_2 and H_2O interference
Other Methods: corrections has yielded results within 1% of instrument

scale when compared to simultaneous tests performed
using the SCAQMD TCA method.

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